

1                   **AN ELECTRICAL COMPONENT AND A SHUNTABLE/SHUNTED**  
2                   **ELECTRICAL COMPONENT AND METHOD FOR SHUNTING**  
3                   **AND DESHUNTING**

4                   **FIELD OF THE INVENTION**

5                   The present invention relates generally to methods for eliminating or reducing  
6                   potential damage to devices from electrostatic discharge or electrical overstress and  
7                   to such devices, and particularly to methods for reducing such damage to electronic  
8                   components such as but not limited to a magnetoresistive head forming part of a hard  
9                   disk drive.

10                  **BACKGROUND OF THE PRESENT INVENTION**

11                  Damage due to electrostatic discharge (ESD) and/or electrical overstress  
12                  (EOS) costs industry uncounted and perhaps uncountable dollars daily in damaged  
13                  and irreparable goods. More specifically, ESD/EOS damage is a particular problem  
14                  in the electronics industry where the components are, of course, designed to conduct  
15                  electricity in the first instance and where their continuously shrinking size renders  
16                  them increasingly susceptible to such damaging effects. Generally, ESD refers to

1 actual discharges while EOS refers to the effects of such discharges or currents  
2 induced by such discharges or other electrical or magnetic fields. For present  
3 purposes, reference to one should be interpreted to include the other.

4 ESD, familiarly manifested by the lightning bolts or by the shock received  
5 when touching a door knob, after walking across a carpet, can range from a few volts  
6 to as much as several thousand volts, resulting in extremely large transient currents.  
7 As electronic components shrink in size they become ever more susceptible to  
8 damage from smaller and small voltages and current.

9 ESD can arise in several different ways, most commonly as a result of  
10 triboelectric charging or induction. Triboelectric charging causes a charge build up  
11 due to the frictional engagement of two objects. That is, static charge builds up as  
12 a result of a series of contacts and separations of two objects. Electrons travel from  
13 one object to the other during these contacts depending on the relative abilities of the  
14 objects to gain or lose electrons, that is, depending upon the position of the two  
15 objects in the electrochemical potential series. Consequently, a net charge of  
16 opposite sign will build up and remain on both of the objects after their separation.  
17 Where the object has good conductivity and is grounded, charge will flow to the  
18 ground. If the electric field generated by the separated charges is strong enough, an  
19 electrostatic discharge can occur in form of a spark traveling across an air gap from

1 one object towards an object at a lower electrostatic potential, thus providing the  
2 familiar blue light generated by the spark. This discharge can occur either as one  
3 object is brought next to one of the charged objects or as one object is separated from  
4 the other.

5 Static charges can also build up by induction. That is, if a charged object is  
6 brought near an uncharged object, the electric field of the charged object will induce  
7 a charge in the object, generating an electric field and potentially a static discharge.

8 A goal in many industries, then, is to determine methods and apparatus for  
9 reducing or eliminating static discharges. One of the electronics industries affected  
10 by ESD/EOS damage is that which manufactures and assembles computer hard disk  
11 drives. As noted above, present hard disk drives include a disk rotated at high speeds  
12 and a read/write head that, in industry parlance, "flies" a microscopic distance above  
13 the disk surface. The disk includes a magnetic coating that is selectively  
14 magnetizable. As the head flies over the disk, it "writes" information, that is, data,  
15 to the hard disk drive by selectively magnetizing small areas of the disk; in turn, the  
16 head "reads" the data written to the disk by sensing the previously written selective  
17 magnetizations. The read/write head is affixed to the drive by a suspension assembly  
18 and electrically connected to the drive electronics by an electrical interconnect. This

1 structure (suspension, electrical interconnect, and read/write head) is commonly  
2 referred to in the industry as a Head Gimbal Assembly, or HGA.

3 More specifically, currently manufactured and sold read/write heads include  
4 an inductive write head and a magnetoresistive (MR) read head or element or a  
5 "giant" magnetoresistive (GMR) element to read data that is stored on the magnetic  
6 media of the disk. The write head writes data to the disk by converting an electric  
7 signal into a magnetic field and then applying the magnetic field to the disk to  
8 magnetize it. The MR read head reads the data on the disk as it flies above it by  
9 sensing the changes in the magnetization of the disk as changes in the voltage or  
10 current of a current passing through the MR head. This fluctuating voltage in turn  
11 is converted into data. The read/write head, along with a slider, is disposed at the  
12 distal end of an electrical interconnect/suspension assembly.

13 Other types of read heads, such as inductive read heads, are known, but the  
14 MR and GMR elements enable the reading of data that is stored more densely than  
15 that which was allowed with the use of inductive read element technology. MR and  
16 GMR read elements are much more sensitive to current transients resulting from  
17 voltage potentials and thermal gradients, however, than the previous read element  
18 technologies. It is now becoming increasingly necessary to manage environmental  
19 electrostatic charge levels to as low 3.3 volts during HGA manufacturing processes

1 so as not to damage the MR and GMR elements. Failing to do so, or failing to  
2 provide an avenue for the safe discharge of the accumulated electrostatic charge can  
3 result in damage to the MR and GMR heads.

4 Damage to an MR or GMR head can be manifested as physical damage or  
5 magnetic damage. In the former, melting of the read element in the head can occur  
6 because of the heat generated by the transient current of the discharge. Magnetic  
7 damage can occur in the form of loss of sensing ability and instability. Furthermore,  
8 direct discharge into the head is not necessary to create the damage. Damaging  
9 current flows in the head can also reportedly be created through electromagnetic  
10 interference as a result of a distant (relatively speaking) discharge.

11 An exploded view of a typical electrical interconnect/suspension assembly is  
12 shown in Figure 1, which illustrates several components including a suspension A  
13 and an interconnect B. It will be understood that the actual physical structures of  
14 these components may vary in configuration depending upon the particular disk drive  
15 manufacturer and that the assembly shown in Figure 1 is meant to be illustrative of  
16 the prior art only. Typically, the suspension A will include a base plate C, a radius  
17 (spring region) D, a load beam E, and a gimbal F. At least one tooling aperture G  
18 may be included. An interconnect B may include a base H, which may be a synthetic  
19 material such as a polyimide, that supports typically a plurality of electrical traces or

1 leads I of the interconnect. The electrical interconnect B may also include a  
2 polymeric cover layer that encapsulates selected areas of the electrical traces or leads  
3 I.

4 Stated otherwise, suspension A is essentially a stainless steel support structure  
5 that is secured to an armature in the disk drive. The read/write head is attached to the  
6 tip of the suspension A with adhesive or some other means. The aforementioned  
7 electrical interconnect is terminated to bond pads on the read/write head and forms  
8 an electrical path between the drive electronics and the read and write elements in the  
9 read/write head. The electrical interconnect is typically comprised of individual  
10 electrical conductors supported by an insulating layer of polyimide and typically  
11 covered by a cover layer. Prior to the time that the HGA is installed into a disk drive,  
12 the electrical interconnect is electrically connected to the read and write elements, but  
13 is not connected to the drive electronics. As a result, the individual conductors that  
14 make up the electrical interconnect, can easily be charged by stray voltages, thereby  
15 creating a voltage potential across the sensitive MR or GMR read elements, which  
16 when discharged results in damaging current transients through the read element.

17 The components shown in Figure 1 as well as all those associated with hard  
18 disk drives are small and continually decreasing in size. Consequently, any tolerance  
19 for ESD/EOS damage of the components during the assembly process is also

1 continuously decreasing while their susceptibility to damage during assembly is  
2 increasing.

3 As noted, an ESD can actually damage or destroy circuit pathways in small  
4 electronic parts, such as an MR head, requiring the head to be discarded. The  
5 industry has been so concerned about this costly manufacturing problem that  
6 numerous patents have issued addressing the problem, including but not limited to  
7 U.S. Patent Nos. 5,867,888 for Magnetic Head/Silicon Chip Integration Method;  
8 5,855,301 for Electrostatic Grounding System for a Manually Operated Fluid  
9 Dispenser; 5,843,537 for Insulator Cure Process for Giant Magnetoresistive Heads;  
10 5,837,064 for Electrostatic Discharge Protection of Static Sensitive Devices Cleaned  
11 with Carbon Dioxide Spray; 5,812,357 for Electrostatic Discharge Protection Device;  
12 5,812,349 for Magnetic Head Apparatus Including Separation Features; 5,761,009  
13 for Having Parastic [sic] Shield for Electrostatic Discharge Protection; 5,759,428 for  
14 Method of Laser Cutting a Metal Line on an Mr Head; 5,757,591 for  
15 Magnetoresistive Read/Inductive Write Magnetic Head Assembly; Fabricated with  
16 Silicon on Hard Insulator for Improved Durability and Electrostatic Discharge  
17 Protection and Method for Manufacturing Same; 5,757,590 for Fusible-Link  
18 Removable Shorting of Magnetoresistive Heads for Electrostatic Discharge  
19 Protection; 5,748,412 for Method and Apparatus for Protecting Magnetoresistive

1       Sensor Element from Electrostatic Discharge; 5,742,452 for Low Mass Magnetic  
2       Recording Head and Suspension; 5,732,464 for Method of Facilitating Installation  
3       or Use of an Electromechanical Information-Storage Device Drive Assembly;  
4       5,710,682 for Electrostatic Discharge Protection System for Mr Heads; 5,699,212 for  
5       Method of Electrostatic Discharge Protection of Magnetic Heads in a Magnetic  
6       Storage System; 5,686,697 for Electrical Circuit Suspension System; 5,654,850 for  
7       Carbon Overcoat with Electrically Conductive Adhesive Layer for Magnetic Head  
8       Sliders; 5,650,896 for Low Cost Plastic Overmolded Rotary Voice Coil Actuator;  
9       5,644,454 for Electrostatic Discharge Protection System for Mr Heads; 5,638,237 for  
10       Fusible-Link Removable Shorting of Magnetoresistive Heads for Electrostatic  
11       Discharge Protection; 5,589,777 for Circuit and Method for Testing a Disk Drive  
12       Head Assembly Without Probing; 5,491,605 for Shorted Magnetoresistive Head  
13       Elements for Electrical Overstress and Electrostatic Discharge Protection; and  
14       5,465,186 for Shorted Magnetoresistive Head Leads for Electrical Overstress and  
15       Electrostatic Discharge Protection During Manufacture of a Magnetic Storage  
16       System.

17               The foregoing patents generally evidence four different methods for reducing  
18       or eliminating ESD damage to MR heads, each relying upon the minimization of the  
19       voltage potential across the read elements or dissipation of the static electric charge --



1 that is, the creation of an electrical short -- and not the prevention of its buildup in  
2 the first instance. These methods include the use of mechanical clips, solder bridges,  
3 conductive tape, or a tear-away or sheared etched electrical shunt that is  
4 manufactured into the HGA by vapor deposition and etching or some other process.  
5 While each of these methods has met with some success, each has its own particular  
6 disadvantages. For example, mechanical clips are relatively expensive and also  
7 require a substantial amount of manual labor to attach them to the electrical  
8 interconnect; solder bridges are difficult to attach and then remove without causing  
9 damage to sensitive parts, can be a source of contamination in the drive, and also  
10 require manual labor for solder application and removal; conductive tape is  
11 expensive and requires manual labor for application; and tear away shunts require  
12 expensive apparatus, prohibit the electrical interconnect manufacturer from  
13 performing badly needed in-process continuity checks on the electrical interconnect,  
14 and is intentionally designed as a one-time shunt.

15 There are disadvantages that are shared by all of the above methods. First,  
16 each method is essentially a one-time application of an electrical short. That is, each  
17 of these methods relies upon a one-time placement and subsequent removal of the  
18 electrical short. Preferred manufacturing and quality testing operations, however,  
19 may require the successive application and removal of electrical shorts. For example,

1 prior to in-process read/write head characterization, the electrical interconnect must  
2 be de-shunted, and then re-shunted after the head characterization to prevent ESD  
3 damage later in the manufacturing process. Yet, as noted, most of the foregoing  
4 methods of providing shunts are limited in their ability to be reapplied. This inability  
5 to repeatedly create and remove electrical shorts as desired is a critical limitation in  
6 present manufacturing operations. In addition, the very act of placing and,  
7 particularly, removing the electrical short can cause the very ESD sought to be  
8 avoided and, therefore, the damage that the short was to prevent in the first instance.

9 Further, each of the foregoing methods relies upon a physical engagement  
10 with the critical components of the MR head with at least one and sometimes two or  
11 more physical contacts, at least with the shunt itself and also, depending upon the  
12 shunting method used, with the tool applying the electrical shunt itself to the head.  
13 Each of these engagements and disengagements carries with it the potential for  
14 damaging the head.

15 Broadly stated, it would be desirable to have a method of creating and  
16 removing electrical shorts as desired in sensitive electronic components that did not  
17 depend upon a physical application of a conductive circuit to the component. More  
18 specifically, it would be desirable to have a method of creating and removing an

1 electrical short to prevent ESD/EOS damage in an MR head when desired and any  
2 number of times desired.

3 SUMMARY OF THE INVENTION

4 It is an object of the present invention to provide new and improved apparatus  
5 that is not subject to the foregoing disadvantages.

6 It is another object of the present invention to provide a method of repeatedly  
7 providing and removing electrical shunts to reduce or prevent ESD/EOS damage.

8 It is still another object of the present invention to provide a method of using  
9 radiant energy to create and remove electrical shunts to reduce or prevent ESD/EOS  
10 damage.

11 It is yet another object of the present invention to provide a method of using  
12 a laser beam of a first fluence to create a shunt on the interconnect of the HGA and  
13 of using a laser beam of a second fluence to ablate the shunt.

14 It is another object of the present invention to provide a method of applying  
15 a laser beam to the interconnect of the HGA to create a conductive pathway for the  
16 dissipation of static electrical charges.

1           It is still yet another object of the present invention to carbonize a polymeric  
2 component of the electrical interconnect of an MR head to create a shunt and to  
3 ablate the carbonized surface layer to remove the shunt.

4           The foregoing objects of the present invention are provided by a method for  
5 the substantially at-will creation of conductive pathways for the dissipation of static  
6 electric charges and the subsequent at-will removal of such pathways. The method  
7 includes the steps of providing an interconnect that is electrically connected to at  
8 least one component subject to damage from ESD/EOS; providing a conductive  
9 pathway on the interconnect; removing the conductive pathway when the ESD/EOS  
10 protection is no longer desired or required; and, if desired, re-establishing and  
11 reremoving a new conductive pathway on the interconnect. In one embodiment of  
12 the present invention, the conductive pathway is provided by exposing the  
13 interconnect's polymeric substrate to a radiant energy source. In another embodiment  
14 of the present invention the conductive pathway is removed by exposing the  
15 conductive pathway of the interconnect's polymeric substrate to a radiant energy  
16 source, which may be the same energy source as used to establish the conductive  
17 pathway in the first instance but operated according to different parameters such that  
18 the fluence of the radiant energy source is changed between the establishment and the  
19 removal of the conductive pathways. The fluence may be changed by increasing the

1 operating power of the energy source or by focusing and defocusing the radiant  
2 energy source to alternately concentrate and disperse the energy as desired. In one  
3 embodiment of the present invention a laser beam may be used to create the  
4 conductive pathway.

5 The present invention further provides a method whereby a radiant energy  
6 source may be used either to carbonize a surface layer of a substrate supporting at  
7 least one electrical component or to carbonize the polymeric material that engages at  
8 least one surface of a pair of conductors. The carbonized surface layer of the  
9 substrate or of the cover layer provides an electrical pathway for the controlled  
10 dissipation of static electric charges rather than a damaging discharge (either high  
11 current transients, or a spark). When it is desired to remove the shunt, a radiant  
12 energy source can be used to ablate the carbonized surface, thereby removing the  
13 conductive pathway. Lasers can be used both to carbonize the polymeric surfaces of  
14 an interconnect to create the conductive pathway and to ablate the pathway when  
15 desired.

16 The present invention also provides for interconnects in accord with the  
17 present invention. Such interconnects include at least two conductive wires or leads  
18 engaged on at least one surface by a carbonizable and ablatable material. The  
19 conductive wires may each include a branched dead end lead portion interleaved with

1 the branched dead end lead portion of the other. Alternatively, the conductive wires  
2 may extend in close proximity to each other in a curved or sinuous or serpentine or  
3 backtracking pattern. An interconnect in accord with the present invention may  
4 include a substrate substantially supporting the conductive wires except at  
5 predetermined locations or proposed shunt sites wherein there is at least one through  
6 hole in the substrate or the cover layer of the substrate or both.

7 The foregoing objects of the invention will become apparent to those skilled  
8 in the art when the following detailed description of the invention is read in  
9 conjunction with the accompanying drawings and claims. Throughout the drawings,  
10 like numerals refer to similar or identical parts.

#### 11 BRIEF DESCRIPTION OF THE DRAWINGS

12 Figure 1 is an illustrative, exploded, perspective view of a typical suspension/  
13 interconnect assembly.

14 Figure 2 is a top plan view of a hard disk drive.

15 Figure 3A is a side elevation, partial view of a hard disk drive, such as that  
16 shown in Figure 1.

17 Figure 3B is an enlarged view of the area shown in the phantom circle in  
18 Figure 3A.

1           Figure 4 is a top plan view of an interconnect.

2           Figure 5 is an enlarged sectional view of an interconnect shown in Figure 4  
3 taken along viewing plane 5-5.

4           Figures 6A and 6B illustrate in schematic form an apparatus useful in  
5 practicing the present invention.

6           Figures 7A and 7B illustrate in schematic form another apparatus useful in  
7 practicing the present invention.

8           Figures 8A and 8B illustrate an embodiment of an interconnect in accord with  
9 the present invention showing a cover layer over electrical traces supported on a  
10 substrate.

11          Figure 9 illustrates another embodiment of an interconnect in accord with the  
12 present invention wherein the substrate includes a plurality of through holes.

13          Figures 10A and 8B are obverse and reverse views of an interconnect in  
14 accord with the present invention wherein the substrate includes a plurality of  
15 through holes.

16          Figure 11 illustrates in a perspective view another embodiment of an  
17 interconnect in accord with the present invention that includes a multiply-shutable,  
18 tear-away or shearable portion.

1           Figures 12A and 12B depict an another embodiment of an interconnect in  
2           accord with the present invention that includes a trace pattern having serpentine or  
3           interleaved trace patterns.

4           Figures 13A and 13B show in a perspective view another embodiment of an  
5           interconnect in accord with the present invention that includes a dual layer trace  
6           pattern.

7           Figure 14 illustrates another embodiment of an interconnect in accord with  
8           the present invention including a plurality interleaved "dead end" traces substantially  
9           completely enclosed within a carbonizable cover layer.

10           Figures 15A-15E depict in a cross sectional view the interconnect of Figure  
11           14 taken along viewing plane 15-15 thereof and illustrates a method and interconnect  
12           in accord with the present invention.

13           Figure 16 illustrates in a cross section view another embodiment of an  
14           interconnect in accord with the present invention and shows a plurality of electrical  
15           traces embedded substantially within a single carbonizable, ablatable material.

#### 16           DETAILED DESCRIPTION OF THE INVENTION

17           Figures 2, 3A and 3B illustrate a hard disk drive 10 in a top plan, highly  
18           schematic view. It will be understood that many of the components found in such



1 a disk drive 10, such as a memory cache and the various controllers are not shown  
2 in the figure for purposes of clarity. As illustrated, drive 10 includes at least one, and  
3 typically several, disks 12 mounted for rotation on a spindle 14, the spindle motor  
4 and bearing not being shown for purposes of clarity. A disk clamp 16 is used to  
5 position and retain the disk 12 on the spindle 14. The disk drive 10 further includes  
6 an "E" block 18, best seen in Figure 2. The E block 18 gets its name from its shape  
7 as viewed from the side. It will be observed that E block 18 includes a plurality of  
8 actuator arms 20, 22, and 24, which are supported for pivotal motion by an actuator  
9 pivot bearing 26. A voice coil motor assembly 28 is used to control the pivoting  
10 motion of the actuator arms 20-24.

11 Each actuator arm 20-24 includes a head gimbal assembly 30 comprising a  
12 suspension 32, a read/write head/slider 34, and interconnect 36 that extends from the  
13 head/slider to the actuator flex 38. The dashed circle shows an expanded view of the  
14 arm 20, which includes a substrate 40 (wherein the bracket indicates the lateral extent  
15 of the substrate relative to the actuator arm 20 in this particular embodiment) upon  
16 which electrical leads or traces 42 are supported. The electrical conductors 42 are  
17 typically copper or copper alloy with a gold plating.

18 The substrate 40 will substantially underlie the traces 42. Substrate 40 may  
19 comprise a synthetic material such as polyimide, which may be of the type sold under

1 the brand name Kapton® by I.E. DuPont. Polyimide, as is well known, is an organic  
2 polymer.

3 Figure 4 illustrates in a perspective view an interconnect assembly 44 of the  
4 type in which the present invention may find admirable use. Assembly 44, like that  
5 shown in Figure 1, may have varying configurations depending upon the  
6 manufacturer. Assembly 44 includes a substrate 46 and a plurality of traces or leads  
7 48. The assembly 44 may also include a cover layer 50. Also shown is a window  
8 or gap 49a in the cover layer where the present invention may find application,  
9 though the present invention may find application generally throughout the length of  
10 the assembly 44. The assembly 44 further includes termination pads 54 and may  
11 include test pads 56 in the general area indicated. Typically, that portion including  
12 the test pads 56 will be torn away or removed after testing is complete. The view  
13 taken along cross-section viewing plane 5-5 is shown partially in Figure 5.

14 Referring now to Figure 5, the present invention will be described in broad  
15 detail. Figure 5 illustrates a cross-sectional view of a substrate 58, which may be the  
16 substrate 40, supporting a plurality of spaced apart electrical leads or traces 60, which  
17 may be leads 42. Leads 60 are conductive and may comprise copper wires or other  
18 suitably conductive material. As indicated, a radiant energy source 62, such as ultra  
19 violet light produced by a laser, is applied to the substrate 58 and leads 60. The

1 fluence of the radiant energy is preferentially chosen such that its application to the  
2 substrate 58 results in the "charring" or carbonization of the exposed surface 64 while  
3 leaving the leads 60 unaffected. The carbonized surface layer 64 is conductive, and  
4 thus provides a safe, discharge pathway for any static charges that may build up on  
5 an interconnect or suspension during assembly. Stated otherwise, with the present  
6 invention, the electrical interconnect is shunted, or shorted, by creating a conductive  
7 layer on the substrate surface between adjacent conductors at a site along the  
8 electrical interconnect. In one embodiment of the present invention, when a  
9 polyimide substrate surface at the desired shunt location site is irradiated with  
10 ultraviolet laser light pulses at the proper fluence level, a conductive surface layer,  
11 mainly composed of carbon, is formed. This conductive surface layer provides an  
12 electrical connection between adjacent conductors of the electrical interconnect. In  
13 addition, by increasing the fluence of the applied radiation, the carbonized surface  
14 layer 64 can also be removed, thereby removing the conductive layer and thus  
15 removing the shunt.

16 The carbonized layer produced on a polyimide substrate can exhibit  
17 resistivities as low as 0.05 ohm-cm, depending upon the carbon density of the created  
18 layer. The carbon density of the created conductive surface layer increases with

1 increased pulses of radiant energy and increased fluences, as long as such fluences  
2 remain below the ablation threshold.

3 The present invention, then, provides a method for readily creating and  
4 removing a shunt that is completely devoid of any physical contact of the type that  
5 either can generate static electrical buildups in the first instance or can cause a  
6 discharge in a non-controlled manner. The conductive layer 64 is created by a non-  
7 contact application of a radiant energy, such as ultraviolet electromagnetic radiation,  
8 which may be created using known laser technology, and can be erased, cleaned,  
9 obliterated, or otherwise removed from the substrate as desired. This method enables  
10 the assembler of a hard disk drive or other electronic component to create and  
11 remove an ESD protecting shunt as desired at least once and typically a plurality of  
12 times. In this manner, then, the shunts can be applied, removed, reapplied and re-  
13 removed as desired, thereby maintaining a protective shunt in place at all times  
14 except when such a shunt would interfere with normal assembly or test procedures,  
15 such as when a dynamic electrical test of the read/write head is conducted.

16 The shunting and de-shunting procedures can be repeated at the same site  
17 along the electrical interconnect, or, if desired, at a different site. For shunting  
18 purposes, the size of the irradiated site should be considered in determining how to

1 provide adequate conductivity between conductors. A larger irradiated site length  
2 will provide lower resistance and better shunting performance.

3 Suitable radiant energy sources include excimer lasers or solid-state lasers;  
4 it being understood, however, that any other radiant energy source capable of  
5 preferentially carbonizing the surface of a polymeric material may find employment  
6 with the present invention.

7 More generally, the present invention can be used wherever it is desired to  
8 create a shunt between at least two spatially separated, that is, otherwise electrically  
9 insulated, electrically conductive components at least partially engaging a common  
10 carbonizable insulator, including but not limited to a polymeric substrate or base or  
11 cover layer. A source of radiant energy can be used to apply radiant energy to the  
12 common substrate or base to create a carbonized surface layer interconnecting the  
13 electrically conductive components that will function as an electrical conductive  
14 pathway between them. The surface conductive path can be removed as desired  
15 using a higher fluence radiant energy source.

16 Additionally, the present invention can be used wherever it is desired to  
17 create a shunt between at least two spatially separated, that is, otherwise electrically  
18 insulated, electrically conductive components having at least one surface engaged by  
19 a common polymeric overlay. A source of radiant energy can be used to apply

1 radiant energy to the polymeric overlay to create a carbonized surface layer  
2 interconnecting the electrically conductive components that will function as an  
3 electrical conductive pathway between them. The surface conductive path can be  
4 removed as desired using a higher fluence radiant energy source. It will be  
5 understood that the present invention will also provide for the carbonization of any  
6 other polymeric materials that are disposed between adjacent conductors.

7       Figures 6A, 6B, 7A, and 7B will now be discussed. Figures 6A and 6B  
8 illustrate in schematic form an apparatus 70 useful in accord with the present  
9 invention. As shown, a radiant energy source, such as an ultraviolet laser, 72  
10 provides a radiant beam 74 that is directed through a neutral density filter 76. The  
11 filter 76 operates to reduce the fluence of the beam 74 to a level that is optimal for  
12 creating a carbonized, conductive surface layer on the surface of a workpiece 78,  
13 which may be an interconnect for an HGA by way of example only. A mask 80 is  
14 disposed in the path of beam 74 to pattern the beam in the desired manner and  
15 thereby affect only those portions of the workpiece desired to be affected. The beam  
16 74 is then directed through a focusing means 82 such as the plano-convex lens  
17 illustrated in the drawing and subsequently reflected off a mirror 84, which may be  
18 a 45° ultraviolet-grade mirror, onto the workpiece 78 to produce a carbonized

1 surface. The apparatus 70 can thus be advantageously used to produce a shunt for  
2 an interconnect as previously described.

3 Referring specifically to Figure 6B, when the removal of the carbonized  
4 surface layer is desired, that is, when it is desired to remove the shunt previously  
5 created, the filter 76 can be removed from the path of the beam 74, thus allowing the  
6 full fluence of the beam 74 to be applied to the workpiece 78.

7 Figures 7A and 7B illustrate in schematic form another apparatus 90 useful  
8 in accord with the present invention. As shown in the Figures, a radiant energy  
9 source, such as an ultraviolet laser, 92 provides a radiant beam 94 that is reflected off  
10 a mirror 96, which may be a 45° ultraviolet-grade mirror, through a mask 98 to  
11 control the size and pattern of the beam applied to the workpiece 78 to produce a  
12 carbonized surface. The full fluence of the beam 94 is thus applied directly to the  
13 workpiece. As with the apparatus 70, the apparatus 90 can thus be advantageously  
14 used to produce a shunt for an interconnect as previously described.

15 Referring now to Figure 7B, when the removal of the carbonized surface layer  
16 is desired, that is, when it is desired to remove the shunt previously created, a  
17 focusing means 100, such as the plano-convex lens shown in the figure, can be  
18 placed in the path of the beam 94, thereby concentrating the full fluence of the beam

1 94 to increase its fluence at the workpiece 78 to a level sufficiently high to ablate the  
2 carbonized surface previously produced on the workpiece 78.

3 It is well understood that certain laser beams do not produce a uniform  
4 fluence across the beam area. Therefore, with certain laser beams it may be  
5 necessary to include a homogenizer to provide a uniform beam.

6 It has been found that a carbonized surface can be produced on a polyimide  
7 substrate where the fluence level of the applied laser beam is about 60 millijoules per  
8 square centimeter ( $\text{mJ}/\text{cm}^2$ ) and that the carbonized surface can be ablated or  
9 otherwise removed at a fluence level of about  $140 \text{ mJ}/\text{cm}^2$ . Thus, in Figure 6A, the  
10 radiant energy source 72 would produce a raw beam having a fluence level of about  
11  $140 \text{ mJ}/\text{cm}^2$ , which is subsequently moderated by the filter 76 to a fluence level of  
12 about  $60 \text{ mJ}/\text{cm}^2$  while the radiant energy source 92 of Figures 7A and 7B would  
13 produce a beam having a raw power level of  $60 \text{ mJ}/\text{cm}^2$  which is subsequently  
14 concentrated by the focusing means 100 to produce a power level of  $140 \text{ mJ}/\text{cm}^2$ .  
15 Other fluence levels can also be used to create and remove shunts on polyimides in  
16 accord with the present invention. Additionally, other materials used to support and  
17 insulate the leads may require other fluence levels.

18 Referring now to Figures 8A and 8B, an interconnect 110 useful in accord  
19 with the present invention is shown in a partial perspective view. Interconnect 110



1 includes a substrate 112 supporting a plurality of electrical leads 114 and a cover  
2 layer 116 comprising an overcoated polymer. Cover layer 116 can be in the form on  
3 one or more segments, with adjacent segments defining therebetween a "potential  
4 shunting sector," that is, an area or window 118 of the interconnect 110 that will be  
5 subject to shunting and deshunting. Also shown in the Figure are electrical contacts  
6 120.

7 As seen in Figure 8B, a shunt 122 can be created by exposing a portion of the  
8 substrate 112 and cover layer 116 to a radiant energy source to carbonize the surface  
9 layer of both. When the carbon layer 122 is ablated, that is, the shunt 122 is  
10 removed, then the overcoat layer 116 will act as a barrier to assure that the edges of  
11 the energy stream do not create further carbonization and in effect, reshunt the  
12 electrical leads as the previously applied shunt is being ablated.

13 Figure 9 illustrates another embodiment of a portion of an interconnect in  
14 accord with the present invention. Figure 9 illustrates an interconnect 130, which  
15 includes a substrate 132 supporting a plurality of electrical leads 134 and a plurality  
16 of through holes 136 and 138. The through holes 136 and 138 define the limits of  
17 the potential shunt and deshunt area. That is, the through holes 136 and 138 prevent  
18 the formation of a surface conductive layer between the traces 134 since the substrate

1 has been removed as a support. The through holes 136 and 138 thus function  
2 similarly to the cover layer 116, yet avoid the need to lay down the over coat.

3 Referring now to Figures 10A and 10B, another embodiment of the present  
4 invention, which advantageously incorporates the features of the embodiments of  
5 Figures 8A, 8B and 9, will be described. Figures 10A and 10B illustrate an  
6 interconnect 140, which includes a substrate 142 supporting a plurality of electrical  
7 contacts 144, corresponding leads 146, and a cover layer 148 comprising an  
8 overcoated polymer. Cover layer 148 can be in the form on one or more segments,  
9 with adjacent segments defining therebetween a "potential shunting sector" or  
10 shunting window 150. As seen in Figures 10A and 10B, the substrate 142 includes  
11 a plurality of through holes 152. These through holes define the limits of the  
12 substrate area subject to shunting and deshunting. That is, the through holes 152  
13 prevent the formation of a surface conductive layer between the traces 146 since the  
14 substrate has been removed as a support.

15 Another embodiment 160 of an interconnect in accord with the present  
16 invention is illustrated in Figure 11. The interconnect 160 includes a substrate 162  
17 that supports a plurality of leads 164. It will be observed that the interconnect 160  
18 includes a terminal end 166 defining a tear-away or shearable portion 168 and an  
19 electrical connect portion 170. Terminal end 166 includes a plurality of temporary,

1 tear away or shearable shunt electrical pads 172 and a corresponding plurality of  
2 permanent electrical connection pads 174 electrically connected by a similar  
3 corresponding plurality of tear-away or shearable leads 176. Like the connection  
4 pads 174, the shunt electrical pads 172 are supported upon a substrate that produces  
5 a conductive surface area when exposed to a radiant energy source. Thus the surface  
6 areas 178 between the shunt pads 172 can be made electrically conductive. The  
7 terminal end 166 also includes a through hole 180 underlying the tear-away leads  
8 176. Thus, with this embodiment, the areas 178 can be shunted and deshunted in the  
9 manner hereinbefore described. When the shunt is no longer required, the tear-away  
10 portion 168 can be severed from the portion 170, for example, along the dotted line  
11 188. In this manner, then, the entire tear-away portion can be removed from the  
12 finished product and no trace of the shunting/deshunting operation will remain.

13 With the foregoing invention, the thin, carbon surface layer produced on the  
14 interconnect has a high resistivity. It is desirable, however, to minimize the  
15 resistance between adjacent conductors, such that the majority of a current transient  
16 resulting from an ESD event passes through the shunt, rather than the ESD sensitive  
17 device. One manner of affecting the resistance is to vary the length being shunted  
18 and thus vary the resistance. Thus, increasing the length of the area (length of

1 conductors exposed to the shunt) that forms the shunt will decrease the shunt's  
2 resistance.

3 This following equation describes the relation between the shunt resistance  
4 and other variables of interest:

$$R = \rho \frac{L}{WT}$$

5 where:

6 R = Resistance of shunt (ohms)

7 p = proportionality constant of the carbon layer (0.05 to 0.1 ohms-cm)

8 L = Distance between conductors (0.03mm to 0.05mm)

9 W = Length of conductors aligning the shunt

10 T = Thickness of the carbon layer (~50nm).

11 As shown by this equation, the shunt resistance is inversely proportional to the length  
12 W of the conductors in the irradiated site and is directly proportional to the conductor  
13 spacing L.

14 With regards to MR heads, it is generally desirable to provide less total  
15 resistance in the shunt than in the read/write head (since current will follow the least  
16 resistance path). This can be accomplished by meandering the traces back and forth

1 on themselves in a sinuous or serpentine manner since the increased length of the  
2 traces that are shunted results in a decrease in total shunt resistance. Therefore, the  
3 affected length of the traces due to the creation of the shunt by the radiant energy  
4 source can be longer than with normal non-serpentine traces. For example, normally  
5 the length of the traces shunted may be in the range of about 2 to about 4 mm while  
6 the length of the shunted traces may be substantially longer, say 30 mm, where a  
7 serpentine trace path is used. From the equation above, this results in a reduction in  
8 the shunt's resistance of one order of magnitude or a factor of 10.

9 Simply adding length to the traces is insufficient, however, since negative  
10 effects due to the length addition must be avoided. For example, if the length were  
11 to be increased in the zone between the actuator flex termination pads and the head,  
12 it would increase the trace length between the head and preamplifier, thus  
13 diminishing the read and write speed of the head. Positioning of the increased length  
14 due to the serpentine or sinuous patten is thus critical to achieving the desired  
15 increase in trace resistance without compromising the performance of the read/write  
16 head. For example, the serpentine pattern can be disposed past the actuator  
17 termination zone and even past the test pads. In that manner, this extra lead (trace)  
18 length won't affect drive read or write performance, nor will it impact performance  
19 during in-process electrical tests, such as dynamic electrical tests (DET).

1           Figures 12A and 12B illustrate another embodiment of an interconnect in  
2 accord with the present invention that takes advantage of an increased shunt length.  
3 Figure 12A illustrates, then, a portion of an interconnect 190 having a serpentine  
4 trace pattern that provides the desired increased trace length without degrading the  
5 performance of the read/write head. Interconnect 190 includes a substrate 192. The  
6 substrate 192 includes a plurality of conductive contacts 194A-E that may overlay  
7 through holes in the substrate, which thereby allow electrical contact to be made from  
8 both sides of the interconnect 190. Contact 194A is the ground contact, while  
9 contacts 194B and 194C extend to and from the write head and contacts 194D and  
10 194E extend to and from the read head. Leads 196 extend from each of the contacts  
11 194A-E. Thus, a lead 196A extends from ground contact 194A to a ground  
12 termination (not seen). Furthermore, leads 196B and 196C extend from the write  
13 contacts 194B and 194C, respectively and extend to the electrical component to be  
14 protected, such as a write head.. Leads 196D and 196E extend from the read  
15 contacts 194D and 194E, respectively, to form a serpentine pattern as indicated  
16 generally at 198.

17           The placement of the shunt across the serpentine read leads and the write  
18 leads effectively creates a plurality of resistors in parallel, thus lowering the overall  
19 resistance of the shunt relative to the leads. Thus, the present invention also provides

1 a method for creating a plurality of parallel resistors useful as shunts to prevent  
2 damage due to EDS/EOS.

3 Referring now to Figure 12B, another embodiment of an interconnect 200  
4 useful for reducing the potential for damage due to EDS/EOS is shown.  
5 Interconnect 200 depicts a substrate 202 supporting a ground contact 204A, write  
6 contacts 204B, 204C and read contacts 204D, 204E. Leads 206A extend from  
7 contacts or pads 204A-6 respectively. Lead 206A extends from ground contact  
8 204A. Leads 206B and 206C extend substantially linearly from contacts 204B and  
9 204C respectively to the MR head. Lead 206D extends from read contact 204D  
10 towards the MR head and then branches into a plurality of individual leads 208. In  
11 the embodiment shown here, it will be observed that the leads 208 extend  
12 substantially parallel to each other, though the present invention does not require that  
13 the leads be parallel. Lead 206E extends from read contact 204E toward the MR  
14 head and branches into a plurality of leads 210 that are interleaved with leads 208.  
15 The shunt can be applied using the methods previously and hereafter described to the  
16 interconnect 200 substantially anywhere along the length of the traces or leads 206B-  
17 E, though doing so in the area of the interleaved leads 208 and 210 will provide the  
18 previously discussed advantage of lowering the resistance of the shunt relative to the  
19 leads.

1           In each of the Figures 12A and 12B a shunt 212 is shown in a dotted outline  
2           where it could be advantageously created. It will be understood that a shunt could  
3           be advantageously created at other locations and that the use of cover layers and  
4           through holes is also contemplated.

5           As used herein, "serpentine" is not intended to be limited in its scope to a  
6           strictly "back and forth" trace pattern as shown in Figures 12A and 12C. Rather, any  
7           trace or lead pattern that involves intertwining the leads or extending a plurality of  
8           leads from a single lead in an intertwined manner in close proximity to each other is  
9           within the scope of the present invention.

10          Figures 13A and 13B illustrate another embodiment of an interconnect 220  
11          in accord with the present invention that includes a dual layer trace layout. In a dual  
12          trace interconnect, at least one of the the read and/or write trace pair has one trace or  
13          lead on one side of the substrate and another trace on the other side. As seen in the  
14          Figures, interconnect 220 includes a substrate 220 supporting on opposing sides  
15          thereof at least a pair of write contacts 224 and 226 and a pair of read contacts 228  
16          and 230. Contacts 226 and 230 each overlie a though hole 232 extending through the  
17          substrate 222, thereby allowing electrical contact to be made with all four contacts  
18          on one side of the substrate if desired. Write leads 234 and 236 extend from write  
19          contacts 224 and 226 respectively toward the MR head while leads 238 and 240



1 extend from read contacts 228 and 230 respectively. Lead 238 branches into a  
2 plurality of leads 242. Lead 240 extends to a plated through hole 244 which in turn  
3 branches into a plurality of leads 246 that are interleaved with leads 242. The plated  
4 through hole 244 therefore provides conductivity between the obverse and reverse  
5 sides. Creating the shunt 248 shown in phantom, then, across the interleaved leads  
6 242 and 246, then will provide the same form of ESD/EOS protection as that  
7 provided in Figures 12A-12C.

8           Figures 14 and 15 will now be described. Figure 14 illustrates another  
9 embodiment of an interconnect 300 in accord with the present invention.  
10 Interconnect 300 includes a substrate 302 that supports a plurality of traces 304A-  
11 304D, with leads 304A and 304B being write traces, and leads 304C and 304D being  
12 read traces. Leads 304C and 304D branch into a plurality of interleaved dead end  
13 leads 306 and 308 respectively. The dead end leads function similarly to the  
14 interleaved dead end leads of Figures 12B and 13A, but are oriented substantially at  
15 right angles to the longitudinal axis of the interconnect. Figure 14 thus illustrates  
16 that the interleaved dead end leads could be oriented at any angle relative to the  
17 longitudinal extent of the interconnect, that is, parallel to, perpendicular to or any  
18 angle in between, and still provide the function of lowering the resistance of the

1 shunt relative to the leads themselves. Thus, the present invention contemplates that  
2 any orientation of such interleaved leads are within its scope.

3 The interconnect 300 further includes a cover layer 310, which may be  
4 substantially coextensive with the substrate or may be discontinuous. As illustrated  
5 the cover layer 310 not only engages the top surfaces 312 of the traces 304A-304D  
6 but substantially fills the space between them also. Thus, an interconnect in accord  
7 with the present invention may include a plurality of spaced apart traces wherein at  
8 least a pair of the traces will each have a carbonizable material engaged or touching  
9 at least one surface of the traces. The interconnect 300 includes a plurality of traces  
10 encapsulated by carbonizable material, though, as noted, the present invention would  
11 include interconnects where only a single surface of the traces contacted the  
12 carbonizable material as shown in Figures 8A-13B. Such a complete encapsulation  
13 is not necessary, then, for an interconnect to fall within the scope of the present  
14 invention. Furthermore, even though Figures 15A illustrates an embodiment where  
15 the coverlayer touches the top surfaces 312 of the leads, such a cover layer could be  
16 applied to an interconnect except where a trace pattern such as that shown in Figures  
17 12A-14 is present, with the cover layer not covering the top surfaces of the leads in  
18 that area.

1           Reference will now be made to Figures 15A-15E, which illustrate a process  
2 in accord with the present invention. Figure 15A is a cross section of the  
3 interconnect 300 taken along plane 15-15 of Figure 14. Figure 15A illustrates an  
4 interconnect prior to the beginning of the shunting process with a completely intact  
5 cover layer 310. Figure 15B shows the application of a radiant energy 314 such as  
6 that provided by a UV laser source. The applied energy is of sufficient fluence and  
7 duration that the cover layer 310 is ablated as a result of its application to a depth  
8 sufficient to expose the top surface 312 of at least a pair of adjacent conductors.  
9 Alternatively, the interconnect 300 or any other interconnect with a varying trace  
10 pattern could begin the process with the conductors 304B-304D exposed.

11           After the top surfaces 312 of the leads are exposed, a radiant energy 316 of  
12 a second, reduced fluence can be applied to the cover layer to create a carbonized  
13 surface or shunt 318 as previously described between a pair of adjacent leads as  
14 illustrated in Figure 15C. The shunt 318 can be removed as illustrated in Figure 15D  
15 by the application of an ablating radiant energy 320, which may have the same  
16 fluence as the radiant energy 314 and may be from the same source. As previously  
17 noted, a new shunt 322 can then be recreated by the application of a carbonizing  
18 radiant energy 324, which may have the same fluence as radiant energy 316 and may

1 be from the same source. In this manner, then, the shunt may be created, removed,  
2 recreated and re-removed as desired without physically engaging the interconnect.

3 It will be observed in Figures 15A-15E that the process of shunting,  
4 deshunting, and reshunting an electrical component in accord with the present  
5 invention results in an "erosion" or dissipation of the material being carbonized and  
6 ablated. Thus, the embodiment shown in Figures 14 and 15A-15E provide an  
7 advantage over those shown in the other figures in that it provides a ready reservoir  
8 of carbonizable and ablatable material, whereas the other embodiments illustrated in  
9 the other figures would eventually result in an erosion of material away from the  
10 leads.

11 Figure 16 illustrates yet another alternative embodiment 330 of the present  
12 invention wherein the leads 332 are supported by a singular carbonizable and  
13 ablatable material 334. That is, the present invention will find use where the  
14 electrical conductors to be shunted are supported by a substrate of one material and  
15 engaged by a cover layer of a second material and where the conductors are engaged  
16 by a single material. That is, the present invention will prove useful where a pair of  
17 adjacent conductors are engaged by one or more carbonizable and ablatable  
18 materials.

1           The present invention having thus been described, other modifications,  
2 alterations, or substitutions may now suggest themselves to those skilled in the art,  
3 all of which are within the spirit and scope of the present invention. For example,  
4 rather than creating the shunt directly on the substrate, a carbonizable and ablatable  
5 material, such as an adhesive, may be used to fill the spaces between the leads on the  
6 substrate. That is, the adhesive or carbonizable/ablatable filler material could be laid  
7 down between the leads and then could be converted into a shunt and subsequently  
8 removed in any acceptable non-contact method including the application of a radiant  
9 energy source such as a laser beam.

10           In addition, the present invention could find many instances of application  
11 during the process of assembling a hard disk drive. By way of example only and  
12 without any intent to limit the scope of the present invention or the attached claims,  
13 the process could find use while: shunting the slider body of a read/write head;  
14 shunting the suspension; shunting a pre-amplifier; shunting a micro-actuator; creating  
15 a shunt at a site behind the test pads; creating a shunt a site between test pads and  
16 termination pads; creating a shunt at a site between termination pads and head;  
17 creating a shunt at an intermediate circuit between the head and actuator flex; or by  
18 creating a shunt on a dual layer interconnect.

1           In addition, by way of example only and without any intent to limit the scope  
2 of the invention or the attached claims, the present invention finds use with a laser  
3 operating just below the ablation threshold during carbonization; performing the  
4 processes at the circuit(component) level process; performing the process at the head  
5 gimbal assembly or test process; performing the process at the head stack assembly  
6 or test process; performing the process at the drive level assembly or test process;  
7 while parts are fed past the laser and optics; while parts are in a holding tray or  
8 fixture and the tray is positioned with respect to the laser and optics; while the parts  
9 are positioned manually with respect to the laser and optics; while a beam steering  
10 mechanism is used to direct the laser beam at the parts being acted on; while  
11 measuring resistance during the process for process feedback; while the parts are in  
12 an inert environment; while the parts are in an oxygen rich environment; acting on  
13 designs that open at the beam perimeter; acting on polymer fill; acting through the  
14 substrate; where the polymer is acrylic based; where the material is a composite;  
15 using the process in combination with a removable section; using the process on  
16 multiple sites along the interconnect to create a plurality of shunts simultaneously or  
17 at separate times; performing the process with vacuum or air to remove debris; and  
18 while targeting specific resistance values to be achieved in the shunt.

1           In addition, again by way of illustration and not as a limitation on the  
2 invention or the attached claims and as described in some cases above, the present  
3 invention may find use on a coverlayer boundary; coverlayer holes; substrate holes;  
4 trace separation or routing; with an excimer laser; with an imaging lens; with a mask;  
5 with an attenuator; with a laser beam homogenizer; by using the 3<sup>rd</sup> and 4<sup>th</sup> harmonic  
6 of a Nd:YAG laser; with a polymer/conductor; with a polymer and a semi-conductor;  
7 material.

8           As illustrated herein, the present invention finds a wide variety of  
9 applications. It is therefore intended that the present invention be limited only by the  
10 scope of the attached claims below.

11           WHAT IS CLAIMED IS: